GE Grid Solutions

Grid Modernization: Technological Advancements Beyond Smart Grid

John D. McDonald, P.E.

Smart Grid Business Development Leader

IEEE Life Fellow
IEEE PES Substations Committee Chair (2001-2002)
IEEE PES President (2006-2007)
IEEE Division VII Director (2008-2009)
IEEE-SA Board of Governors (2010-2011)
IEEE PES Distinguished Lecturer (since 1999)
CIGRE USNC VP, Technical Activities

IEEE PES Calgary Chapter
October 23, 2019

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Brief Background

BSEE (1973), MSEE (Power Engineering) (1974) - Purdue University

MBA (Finance) (1978) – University of California-Berkeley

45 years full-time work experience in electric power system automation (i.e., Smart Grid)

Worked for four automation system suppliers and 2 international consultants (11 years at GE)

Written 100+ papers and articles, co-authored five books

48 years IEEE and IEEE PES membership (IEEE Life Fellow)

Teach Smart Grid courses for GE, Georgia Tech and IEEE PES

Mentor young professionals; reverse mentored for 3 years

Eagle Scout; Atlanta Area Council Boy Scouts of America (AAC BSA)

Board Member

AAC BSA Explorer Post at GE on STEM (high school boys and girls)

Married 39 years, two children, two grandchildren

Work out with personal trainer for 9 years; run 5K races regularly

Agenda

- Key Industry/Societal Trends
- Smart Grid Concepts
- Holistic Solutions
- Integration of Microgrids and Distributed Generation
- ADMS Software Applications
- Types of Data
- Big Data, Analytics and Enterprise Data Management
- Smart Grid Standards and Interoperability
- Smart Grid Deployments Lessons Learned

Key Industry/Societal Trends

Key Industry/Societal Trends

- ✓ Transitioning from Devices/Systems to Holistic Solutions
- ✓ Success = Technology, Standards, Policy
- ✓ Grid Flexibility + Self Healing + Reconfigurable
- ✓ Electrical Power Distribution Infrastructures Resiliency
- ✓ Big Data, the Cloud and Use of Social Media
- ✓ Convergence of IT and OT to Support Enterprise Data Management

Smart Grid Concepts

Grid Modernization => IT/OT Convergence

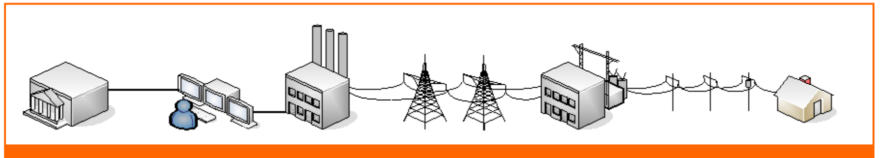
The integration of electrical and information infrastructures, and the incorporation of automation and information technologies with our existing electrical network.

Comprehensive solutions that:

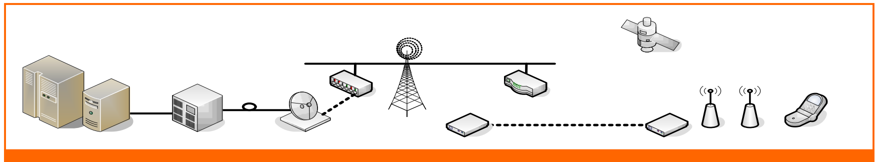
- ✓ Improve the utility's power reliability, operational performance and overall productivity
- ✓ Deliver increases in energy efficiencies and decreases in carbon emissions
- ✓ Empower consumers to manage their energy usage and save money without compromising their lifestyle
- ✓ Optimize renewable energy integration and enabling broader penetration

That deliver meaningful, measurable and sustainable benefits to the utility, the consumer, the economy and the Environment.

More Focus on the Distribution System



Electrical infrastructure



Information infrastructure

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A "Smarter" Grid

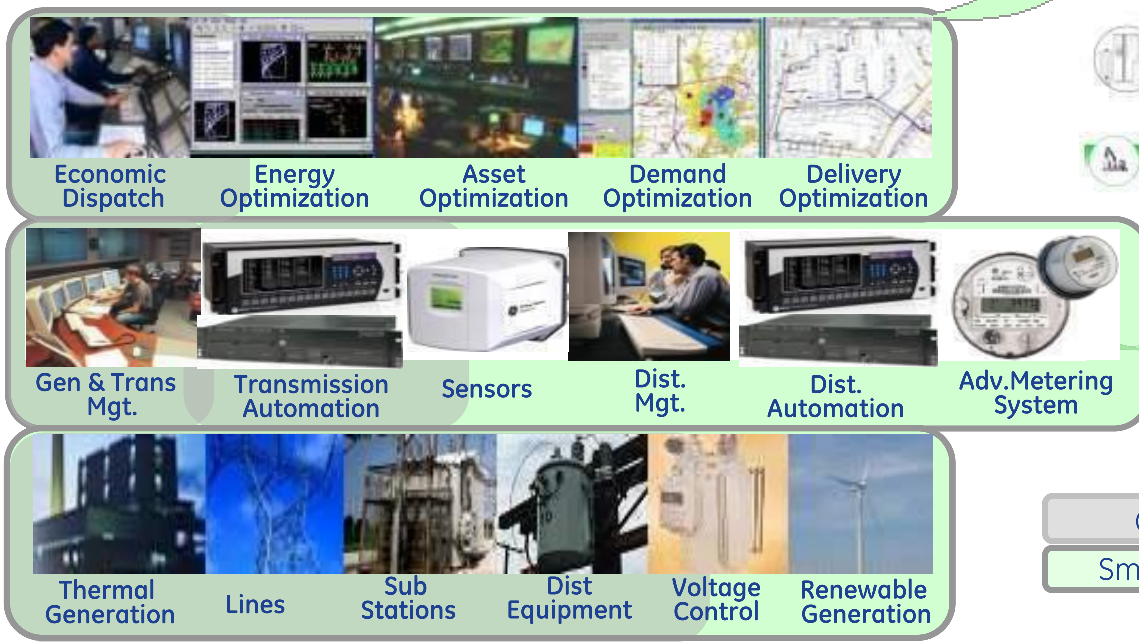
Enabled
Utility Managers

'New Applications enabled by Additional Infrastructure'

Management
" Applications"

Control
"How Power Flows"

Heavy Metal
" Generate & Deliver Power"



Enabled
Consumers

Old Grid
Smart Grid Adds

Old Grid

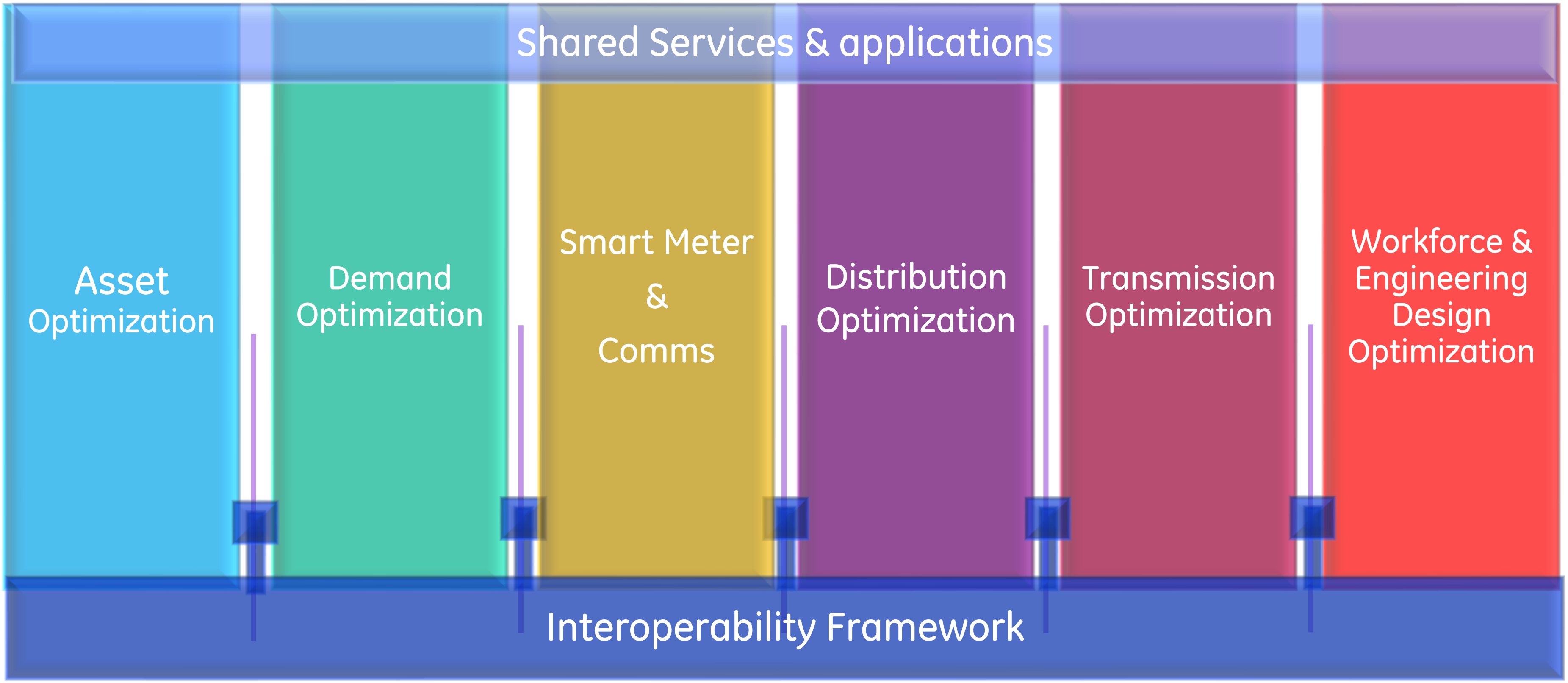
- You call when the power goes out.
- Utility pays whatever it takes to meet peak demand.
- Difficult to manage high Wind and Solar penetration
- Cannot manage distributed generation safely.
- ~10% power loss in T&D

Smart Grid

- Utility knows power is out and usually restores it automatically.
- Utility suppresses demand at peak. Lowers cost. Reduces CAPEX.
- No problem with higher wind and solar penetration.
- Can manage distributed generation safely.
- Power Loss reduced by 2+%... lowers emissions & customer bills.

Holistic Solutions

Smart Grid Holistic Solutions



Transitioning from products/systems to holistic solutions

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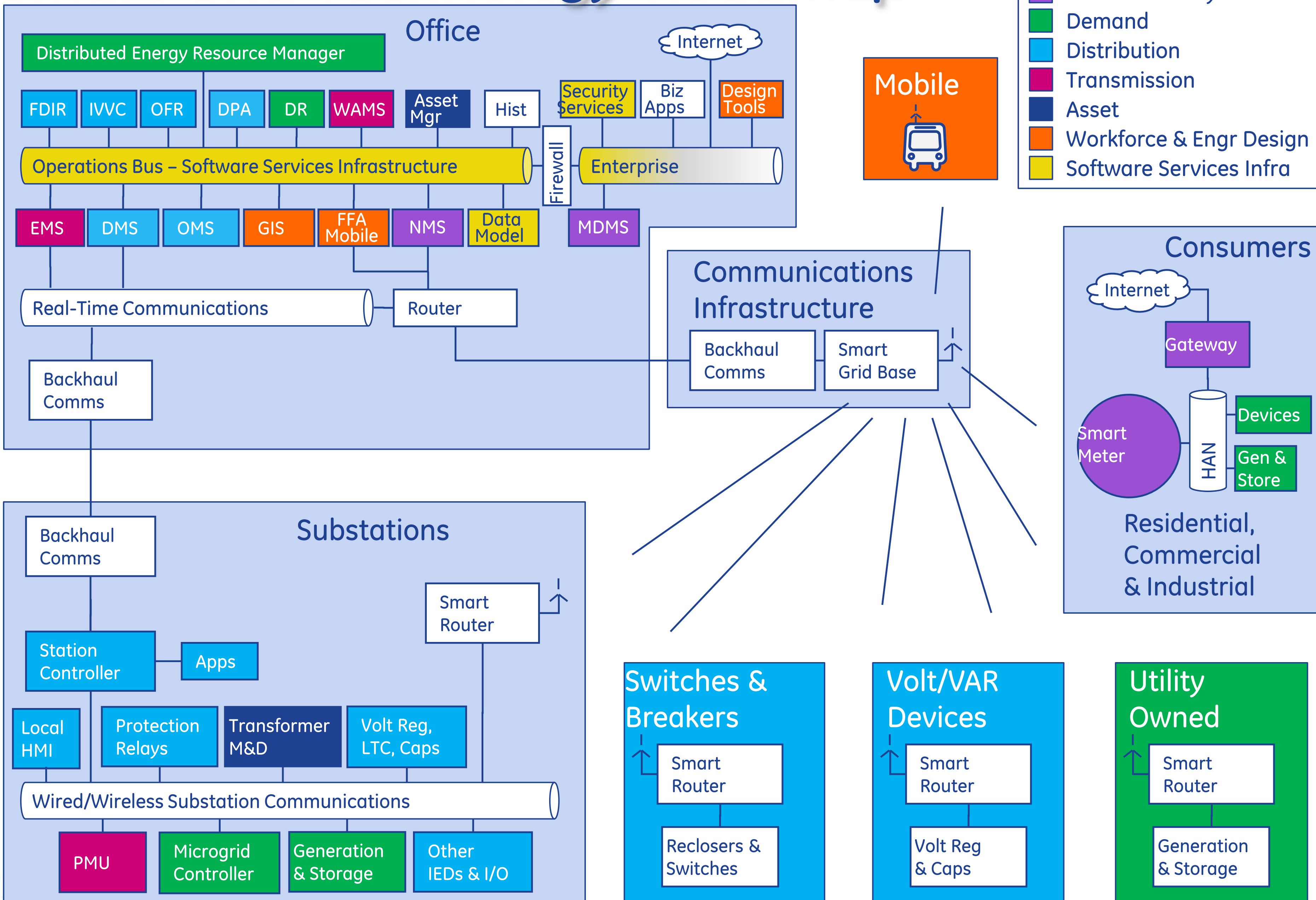
Smart Grid Technology Roadmap

Optimized Solutions
- Smart Meter Systems
- Demand
- Distribution
- Transmission
- Asset
- Workforce & Engr Design
- Software Services Infra



Smart Meters/AMI Integration with GIS, OMS and DMS

Smart Meters/AMI

- Meter Readings
- Voltage => DMS
- Last Gasp Communication => OMS

GIS

- Network Model Information => OMS, DMS

DMS

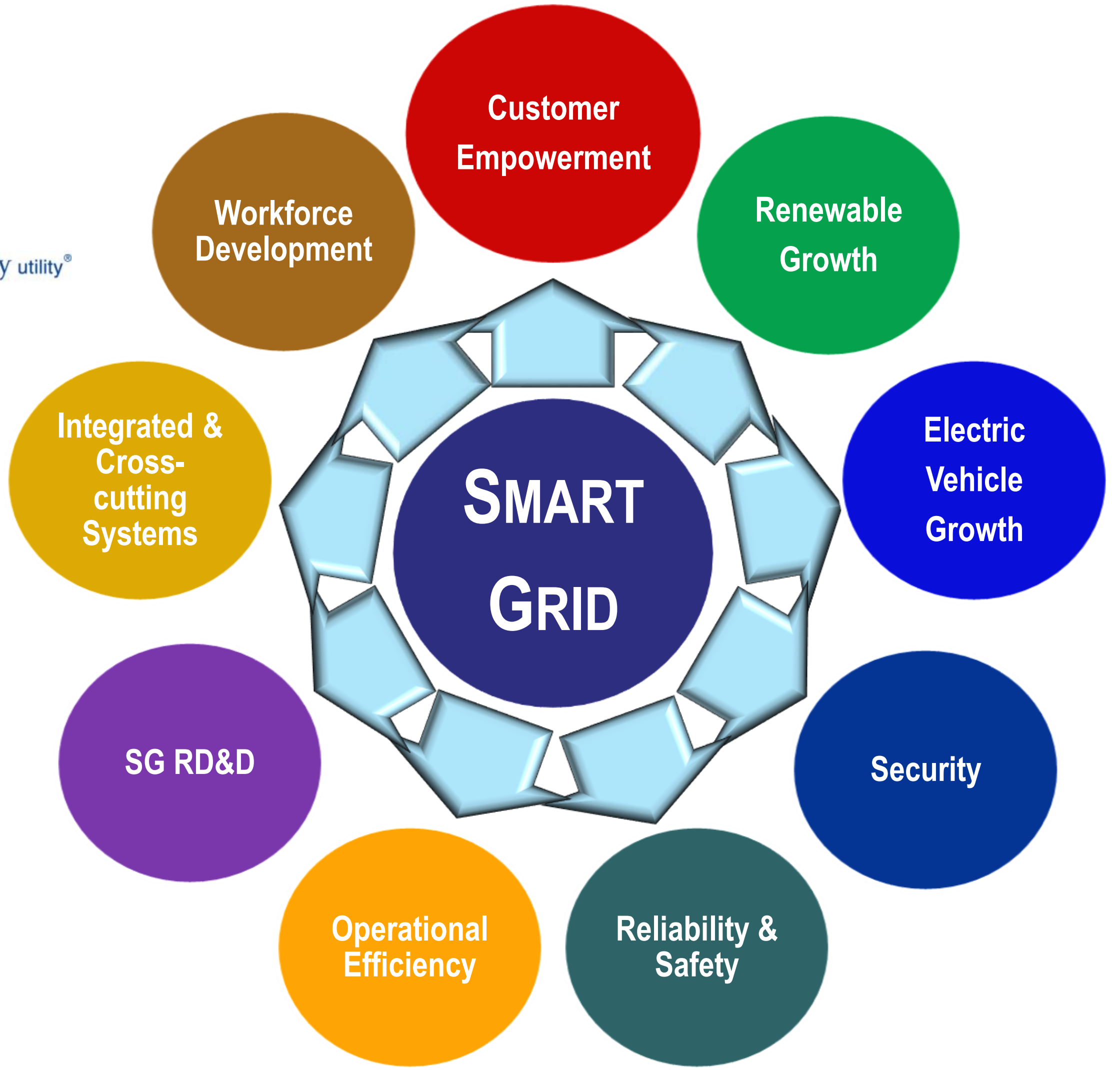
- Status Changes => OMS

Customers

- Phone Calls => OMS
- Social Media => OMS

Example: Utility Deployment Plan

Estimated $3.5B in investment in 9 programs through 2020



SDGE
A Sempra Energy utility®

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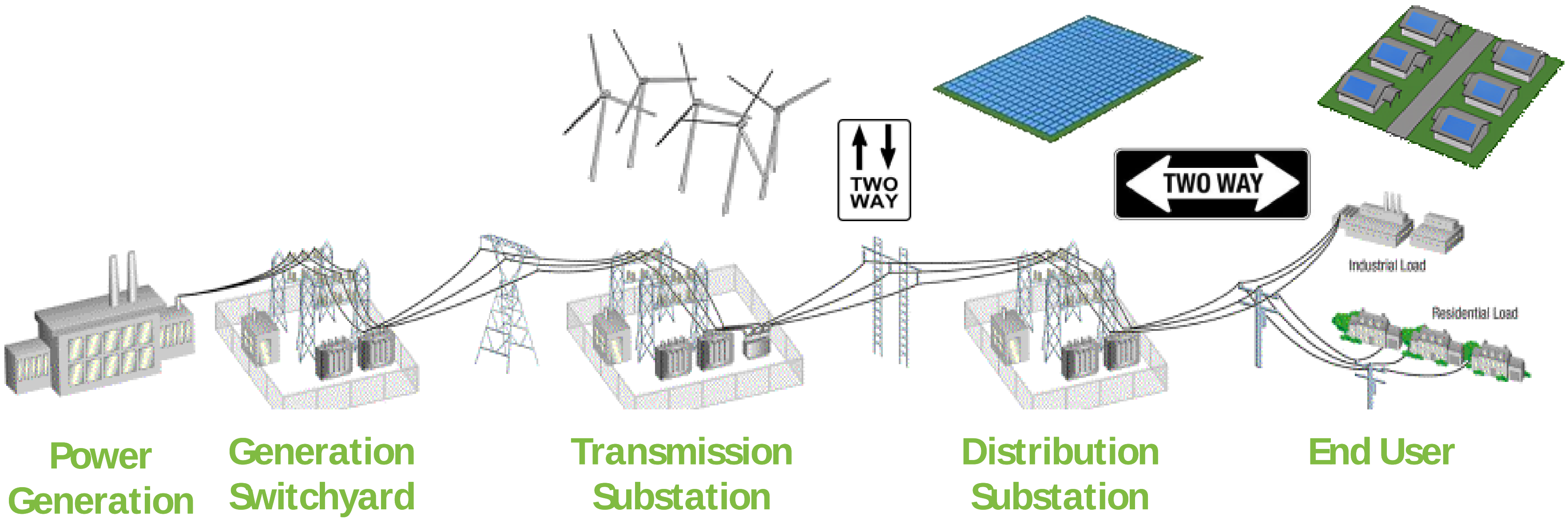
Integration of Microgrids and Distributed Generation

Distributed Generation

Industry Challenge

A wide array of DG is creating unique challenges in the grid: two-way power flow, voltage regulation concerns.



Distribution controls and protection traditionally take advantage of and are designed only for uni-directional power flow

Distributed Generation

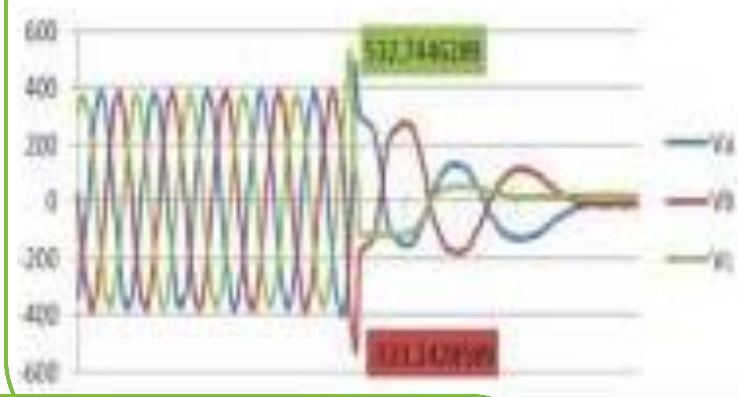
Industry Challenge

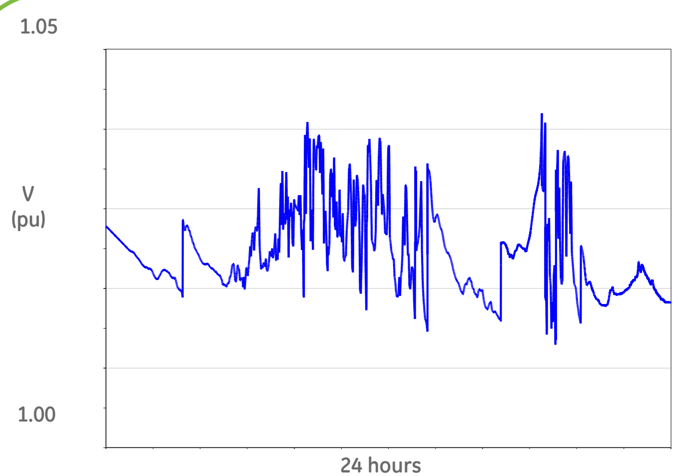
Open circuit over-voltage due to unintentional islanding

Protection ratings not matched to fault currents

Varying Fault Currents due to DG

Stress on Voltage Regulation equipment

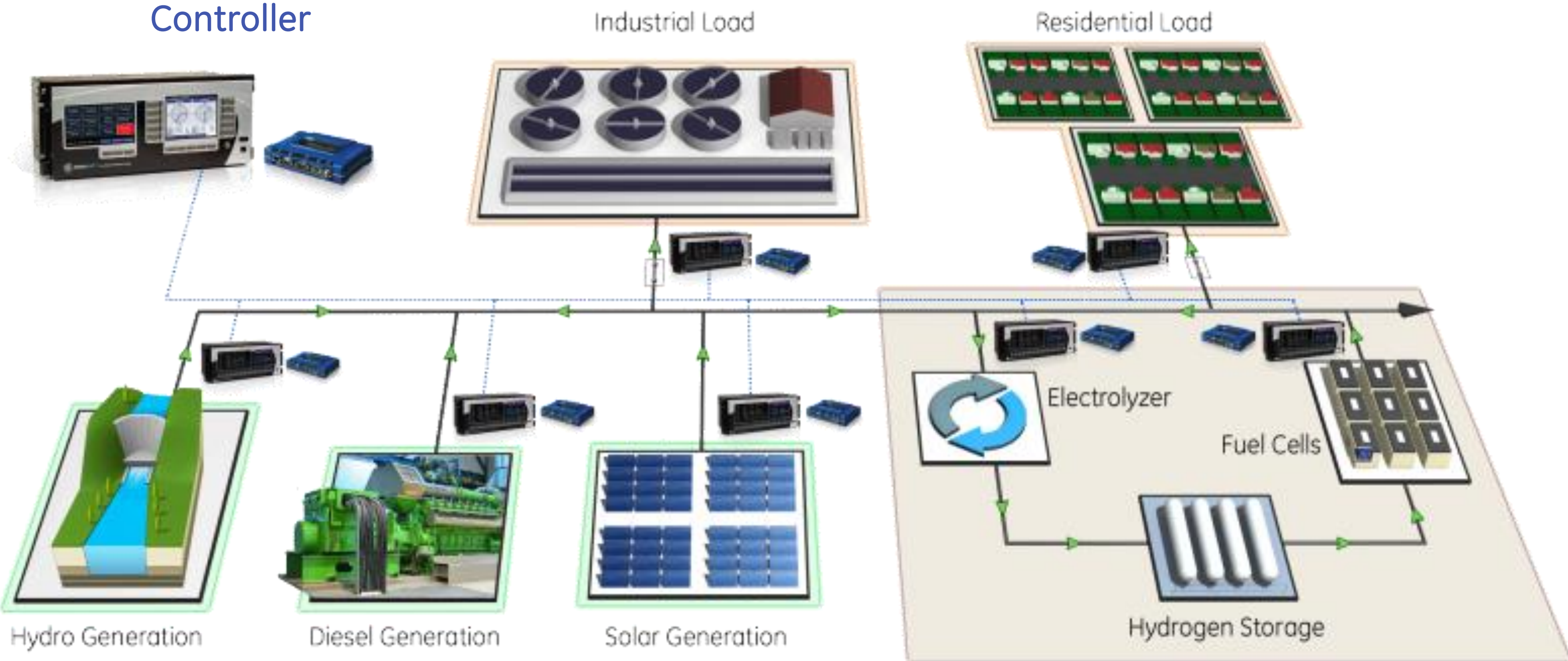




Distributed Generation Integration

Technology Solution   Optimal dispatch of complex energy resources

U90 Microgrid Controller



Smart control system to optimize and manage generators, energy storage and loads featuring:

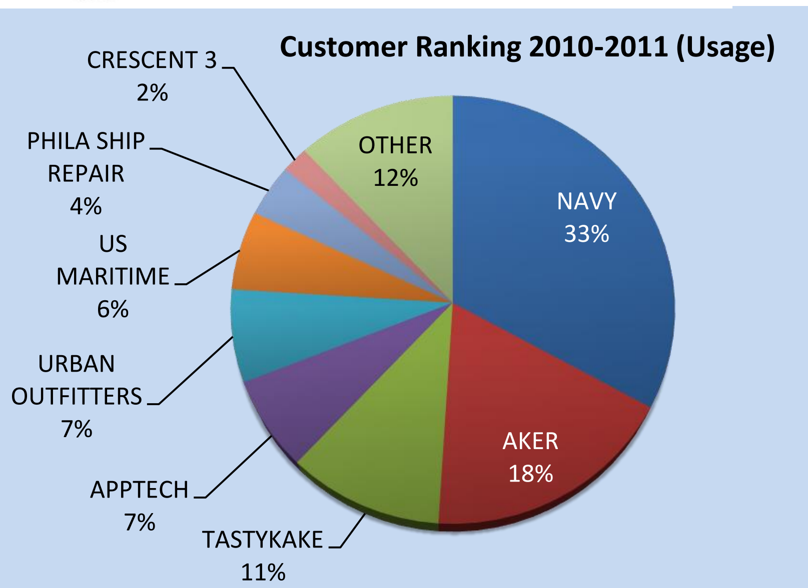
- Optimal Dispatch
- Supervisory Controls
- Islanding/Tie-Line Controls

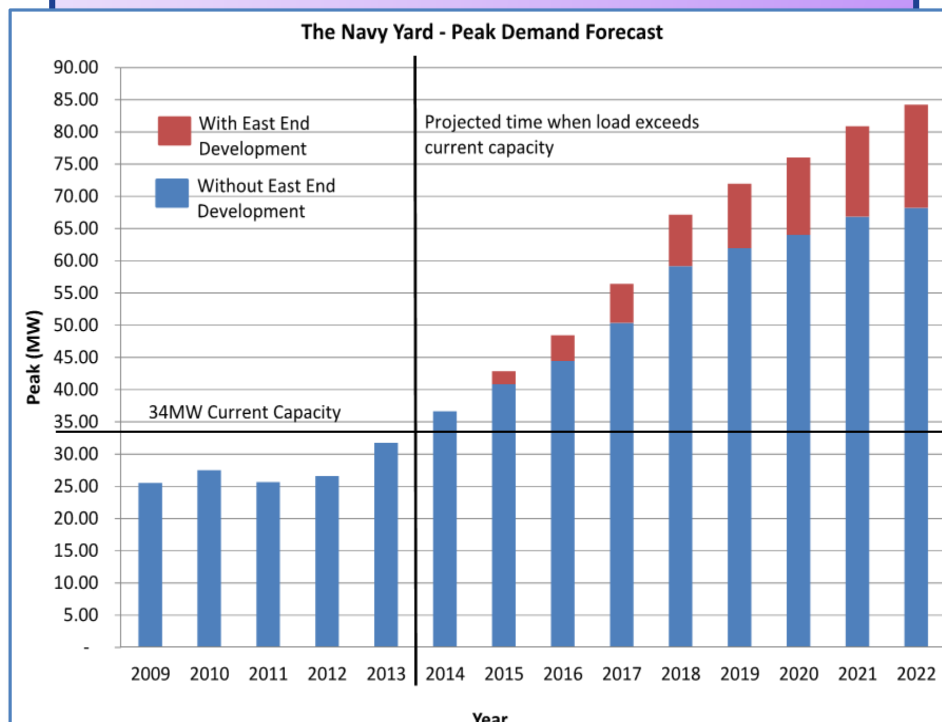
GE's Advanced Microgrid Control System

PIDC's Philadelphia Navy Yard

PIDC (Philadelphia Industrial Development Corporation) - Overview

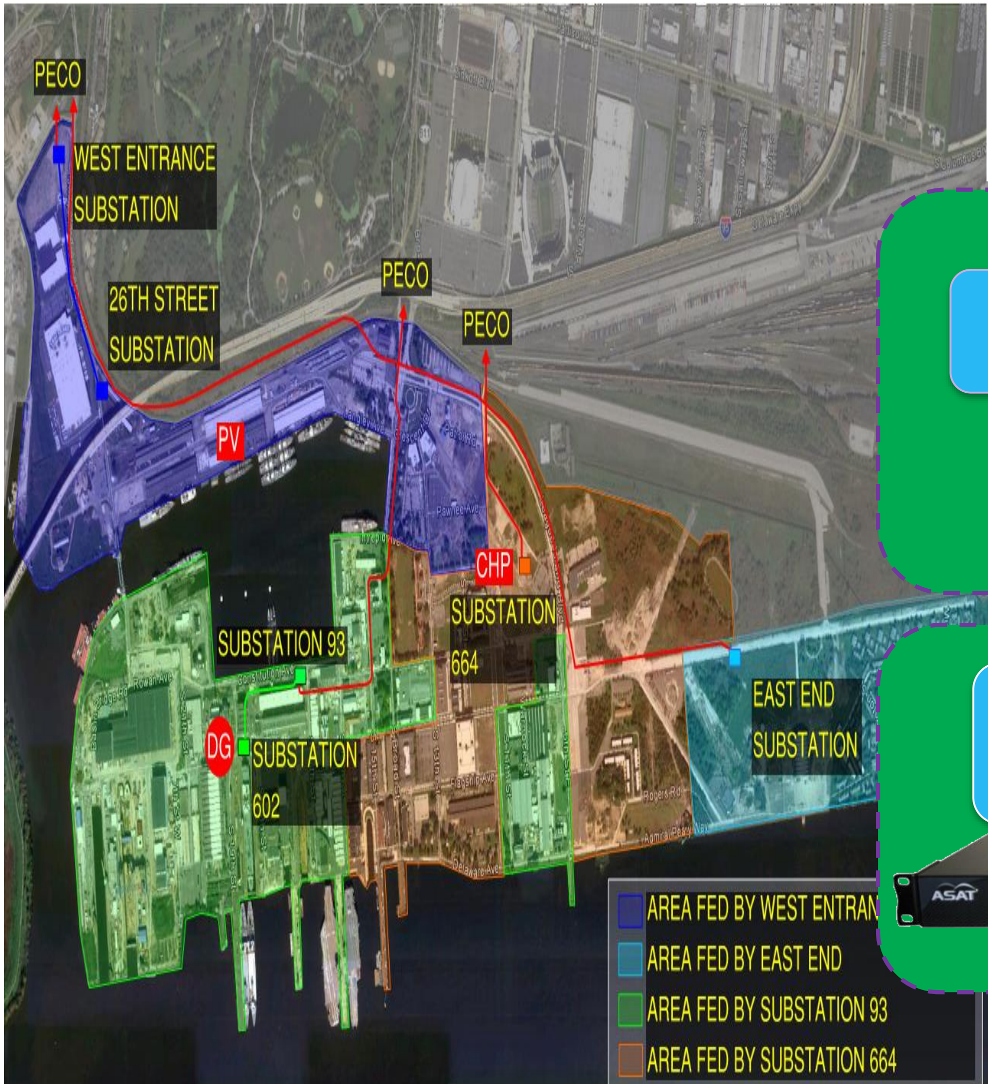
- **Rapid Growth**
- **Vintage 1930s – 2 primary substations**
- **PJM → PECO → 13.2 KV Supply**
- **Current - 25 MW Peak Load**
- **Ambition of 10+ MW DER with 50+ MW**

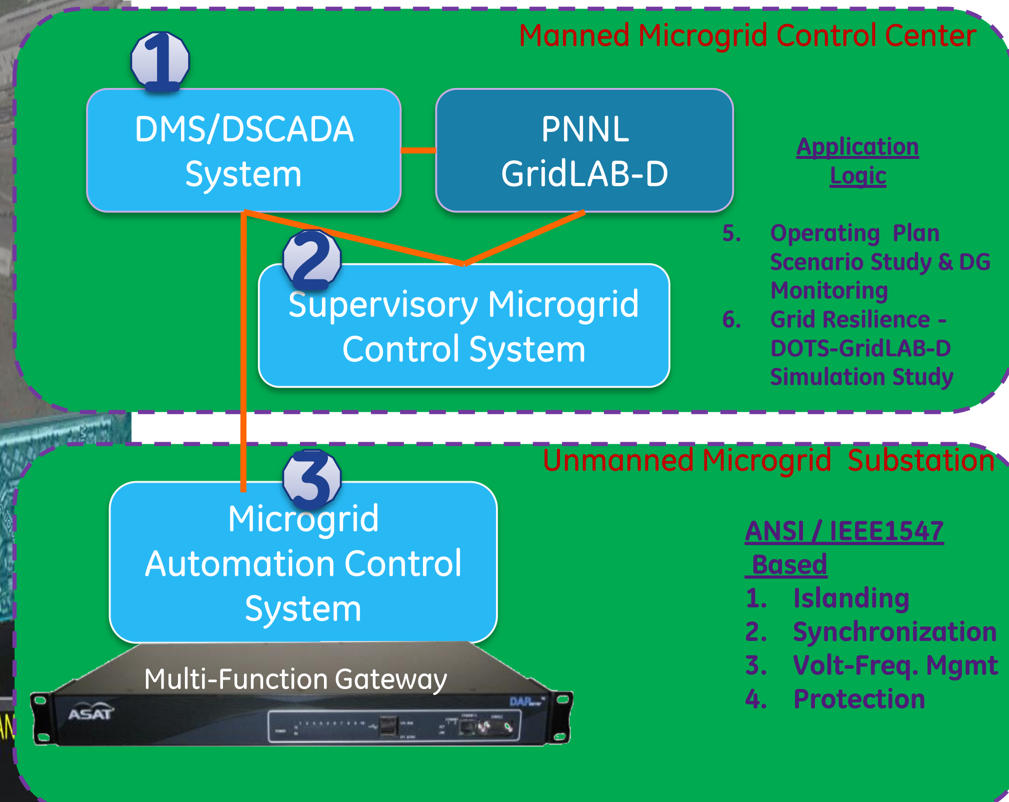




GE's Advanced Microgrid Control System
Philadelphia Navy Yard

U.S. DEPARTMENT OF ENERGY · PIDC · PECO An Exelon Company · pjm · PENNSTATE · The Burns Group





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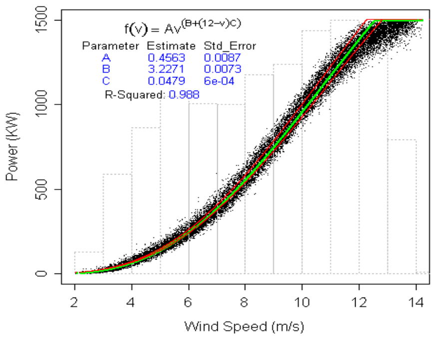
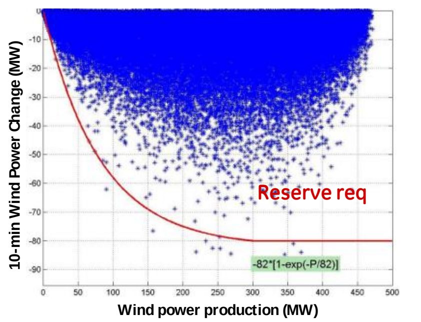
Distributed Generation Integration

Technology Solutions

Optimize conventional generation dispatch

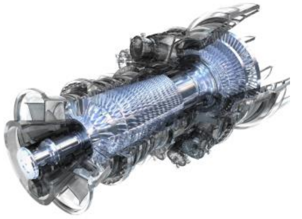
- Leverage production forecasting in optimal dispatch
- Intelligent unit commitment and use of reserves





Compensate for variability when needed

- Use of fast-start thermal generation
- *Bridging* storage (if needed)
- Demand response

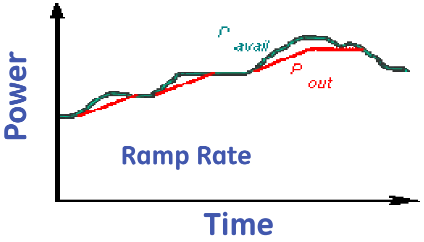


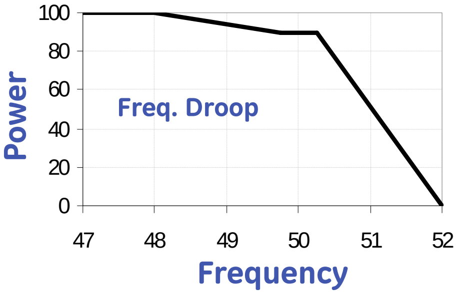
FlexEfficiency 60

GEMx Battery

Leverage full capabilities of the renewables

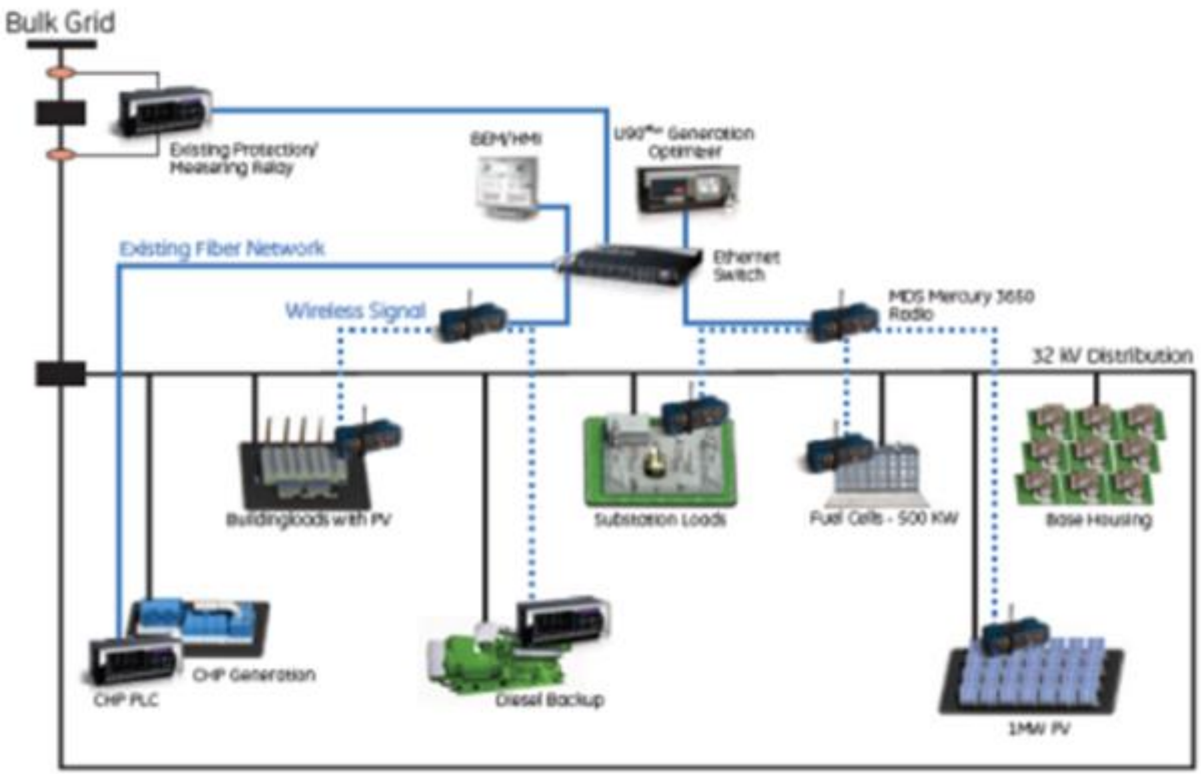
- Fault ride-through
- Volt/VAr regulation
- Ramp-rate controls
- Curtailment
- Inertial response





Grid Edge Controllers and Microgrids

Edge of grid transforming into Microgrids



Impact of High Penetration of Rooftop Solar PV on the Distribution System

New Applications of Power Electronics (my Power Electronics magazine article – August 22, 2013 issue)

- Substation Transformer On-line Tap Changer
- Low Voltage Network Dynamic Grid Edge Controllers
- Increased capability from Inverters

The Death Spiral (Intelligent Utility magazine article – November /December 2013 issue)

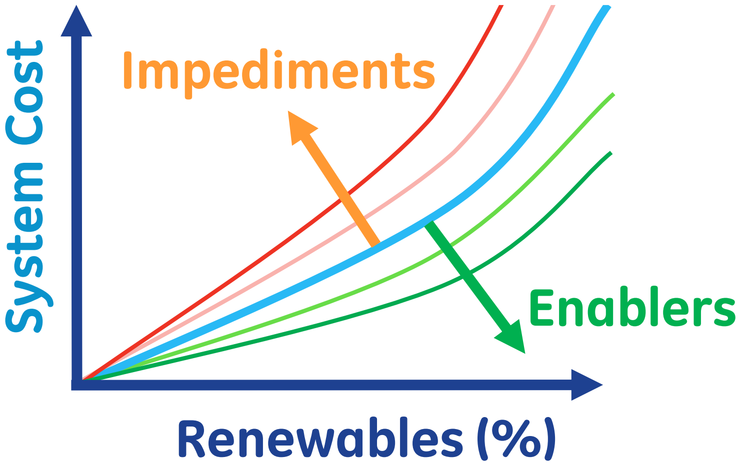
- Impact of High Penetration of Rooftop Solar PV in the State of Queensland, Australia

Lessons Learned…

Impediments
- Lack of transmission
- Lack of control area cooperation
- Inflexibility due to market rules and contracts
- Unobservable DGs – behind the fence
- Inflexible operation strategies during light load & high risk periods

Enablers
- Forecasting
- Thermal fleet
  - Higher quick starts
  - Deeper turn-down
  - Faster ramps
- More spatial diversity
- Renewable + DG + Demand A/S
- Grid-friendly renewables

System cost
- Unserved Energy
- RPS miss
- Higher COE
- Higher Emission
- Higher O&M



Policy and power market structures … key to successful integration of wind and other renewables

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Wind Study References

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- New York State Energy Research and Development Authority's "The Effects of Integrating Wind Power on Transmission System Planning, Reliability, and Operations": http://www.nyserda.ny.gov/~/media/Files/EDPPP/Energy%20and%20Environmental%20Markets/RPS/RPS%20Documents/wind-integration-report.pdf
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  Executive summary http://www.nrel.gov/docs/fy10osti/47781.pdf
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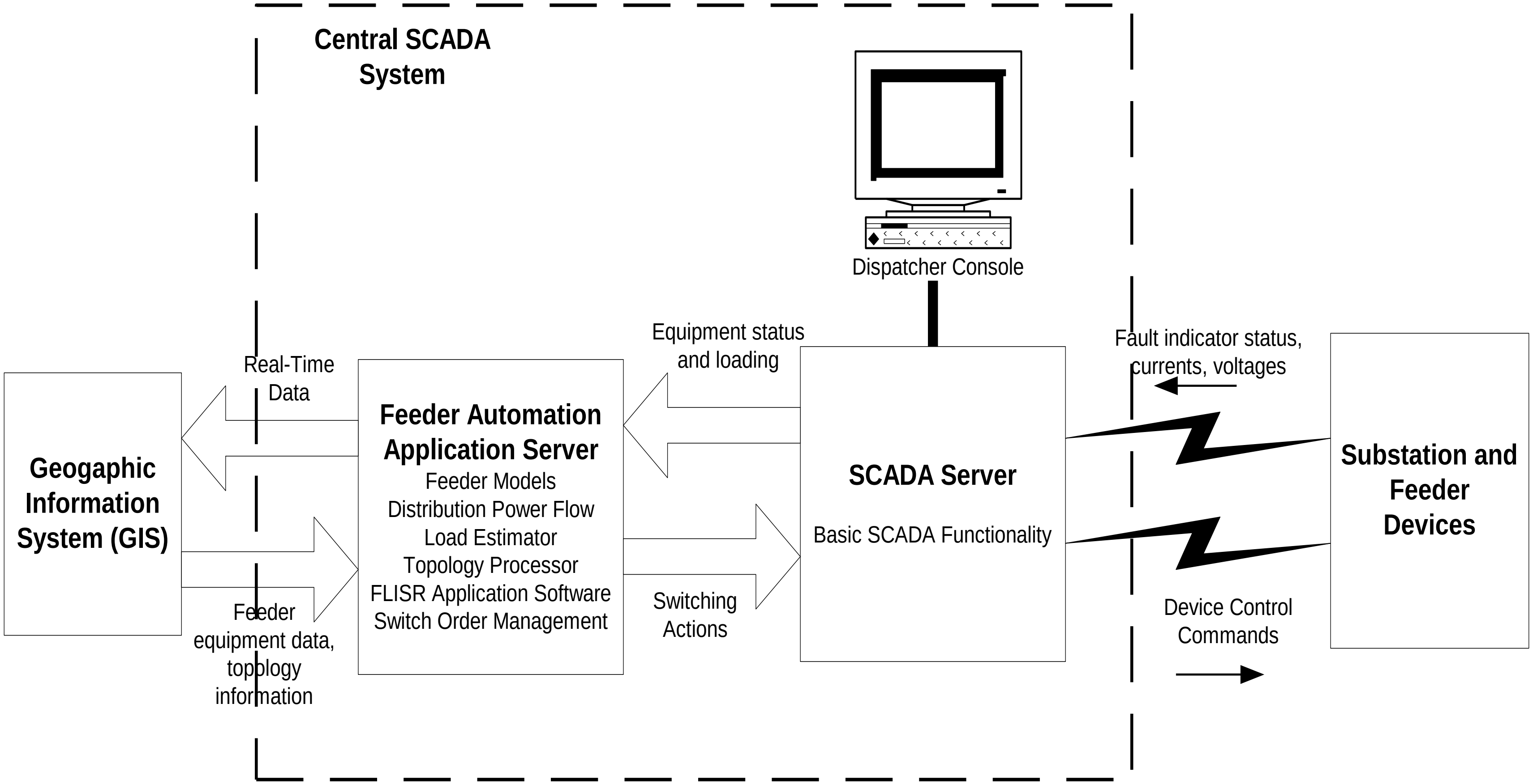
- California ISO, "Frequency Response Study" Oct, 2011 http://www.caiso.com/Documents/Report-FrequencyResponseStudy.pdf
- Nova Scotia Power, "Renewable Energy Integration Study" June 2013 http://www.nspower.ca/site-nsp/media/nspower/CA%20DR-14%20SUPPLEMENTAL%20REIS%20Final%20Report%20REDACTED.pdf
- WWSIS - 3: Western Frequency Response and Transient Stability Study

  Final report http://www.nrel.gov/docs/fy15osti/62906.pdf

  Executive summary http://www.nrel.gov/docs/fy15osti/62906-ES.pdf

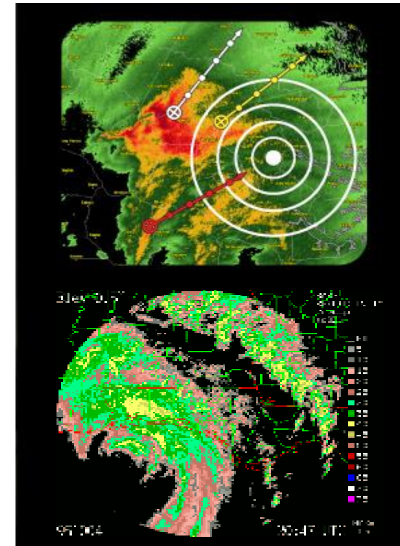
ADMS Software Applications

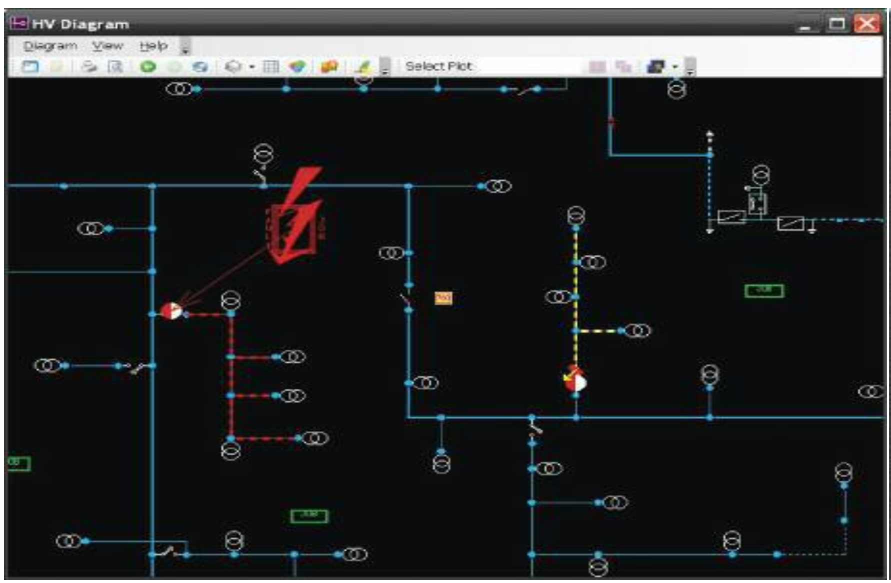
Feeder Automation – Centralized Control

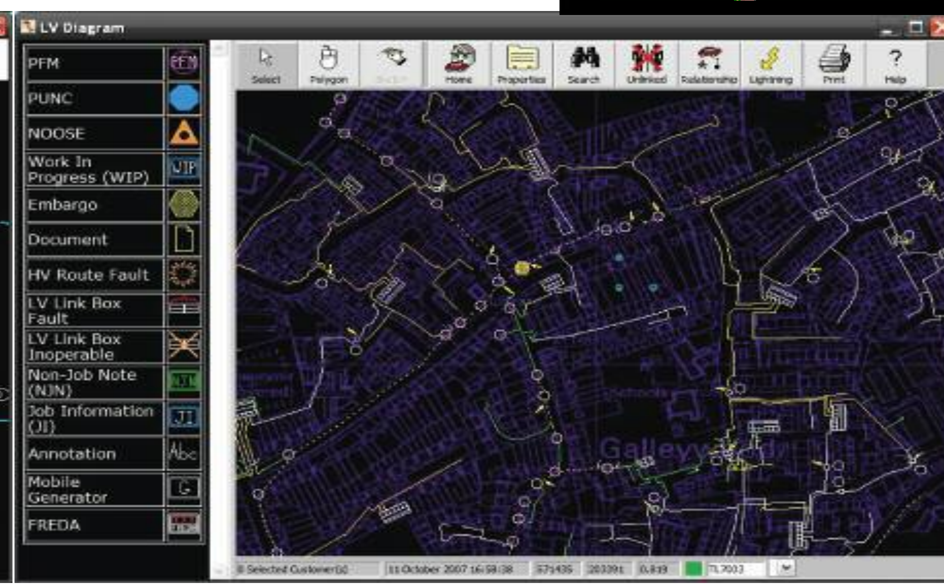


Advanced Real Time DMS Applications

- ❑ **Topology Processor (TP)**
- ❑ **Integrated Volt/VAR Control (IVVC)**
- ❑ **Fault Detection, Isolation, Restoration (FDIR)**
- ❑ **State Estimation (SE)**
- ❑ **Load Estimation (LE)**

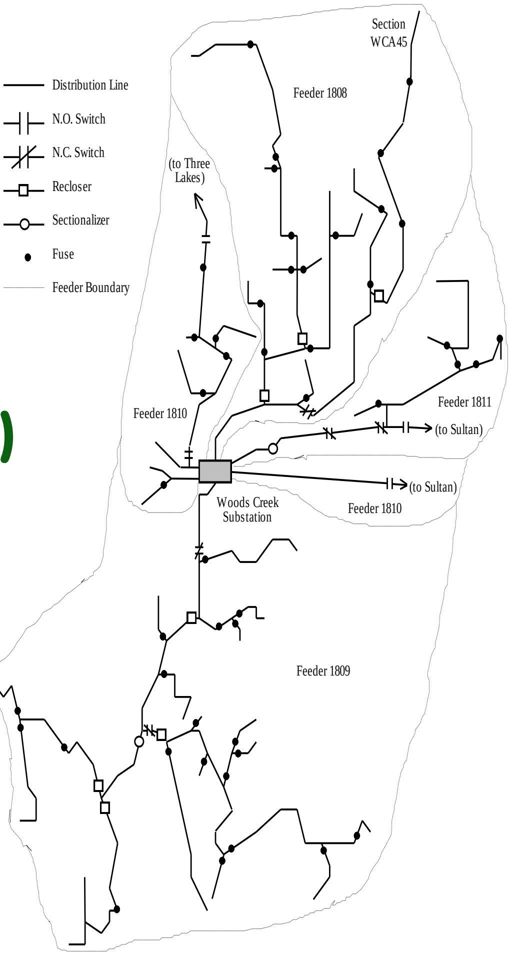






Advanced Analytical DMS Applications

- ❖ **Distribution Power Flow (DPF)**
- ❖ **Short Circuit Analysis (SCA)**
- ❖ **Optimal Feeder Reconfiguration (OFR)**
- ❖ **Optimal Capacitor Placement (OCP)**
- ❖ **Feeder Relay Protection Coordination (RPC)**



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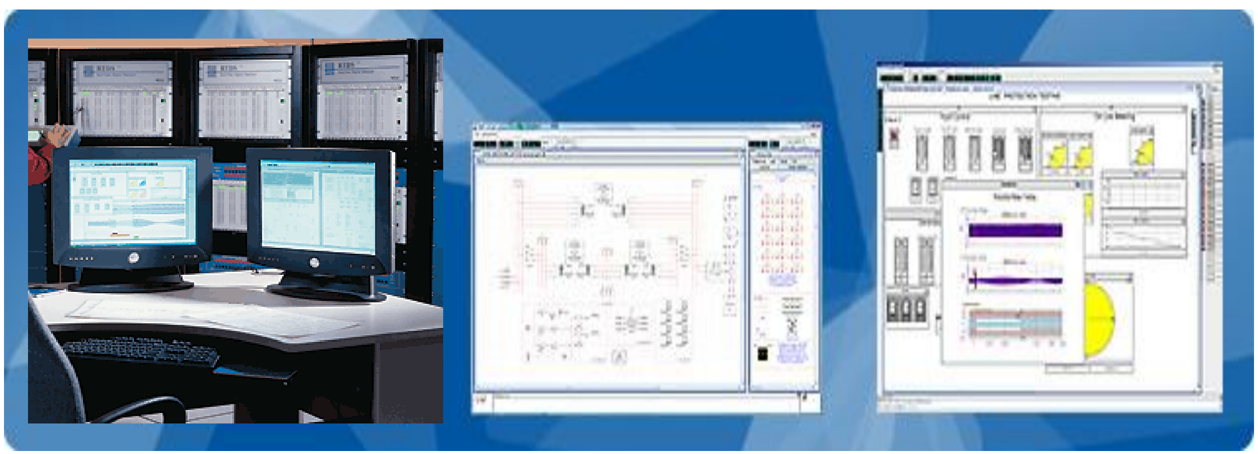
Advanced Ancillary DMS Applications

- Maintenance & Outage Planning (M&OP)
- Power Quality Analysis (PQA)
- Retail Power Marketing (RPM)
- Coordination with adjacent systems
- Distribution Simulation
- .....



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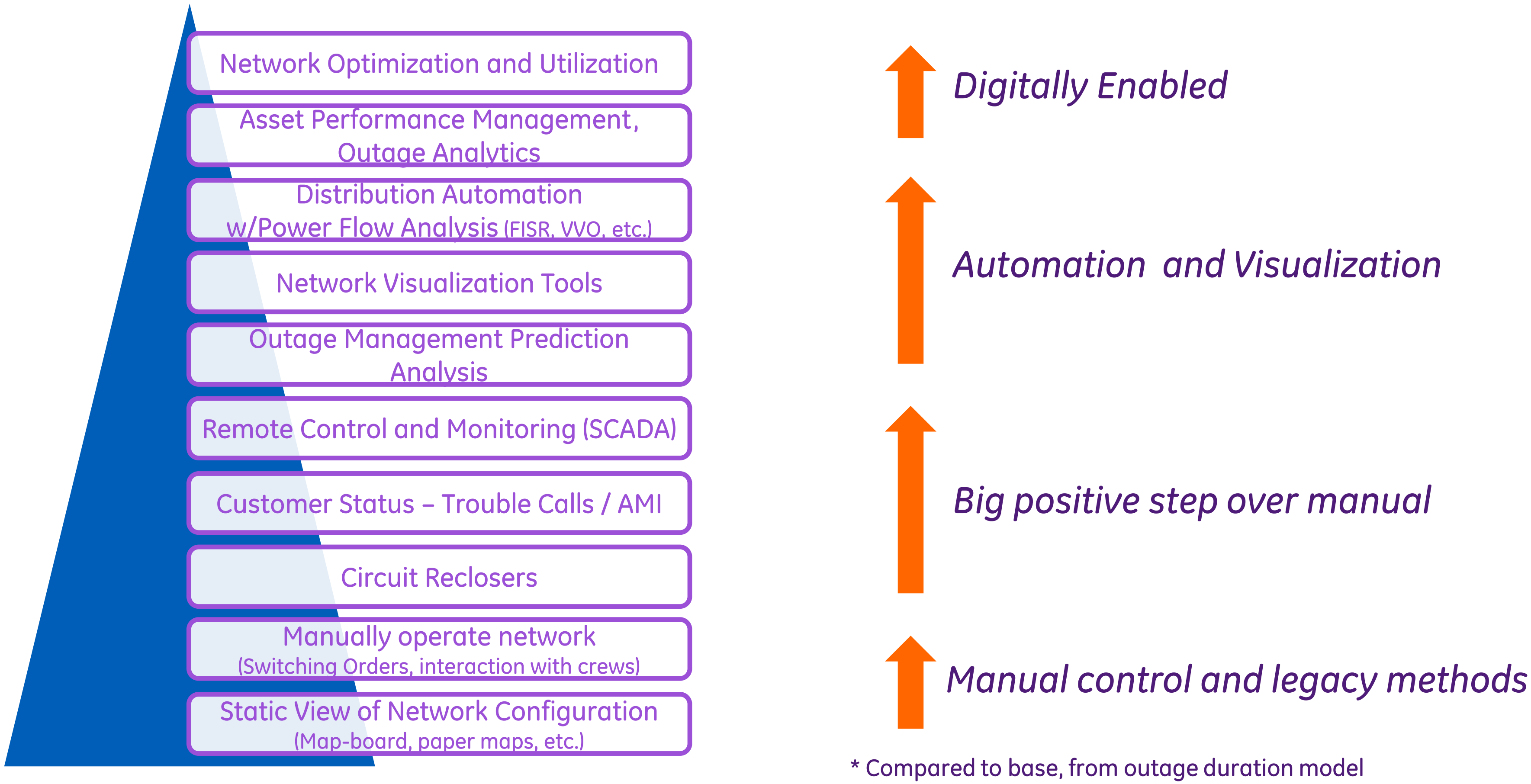
What are the Specific Sets of Feeder Upgrades? For FDIR . . .



* Compared to base, from outage duration model

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What are the Benefits to the Customer from each Upgrade? For FDIR . . .

- Network Optimization and Utilization
- Asset Performance Management, Outage Analytics

>50% Lower CMI * — *Digitally Enabled*

- Distribution Automation w/Power Flow Analysis (FISR, VVO, etc.)
- Network Visualization Tools
- Outage Management Prediction Analysis

43% Lower CMI * — *Automation and Visualization*

- Remote Control and Monitoring (SCADA)
- Customer Status – Trouble Calls / AMI
- Circuit Reclosers

28% Lower CMI * — *Big positive step over manual*

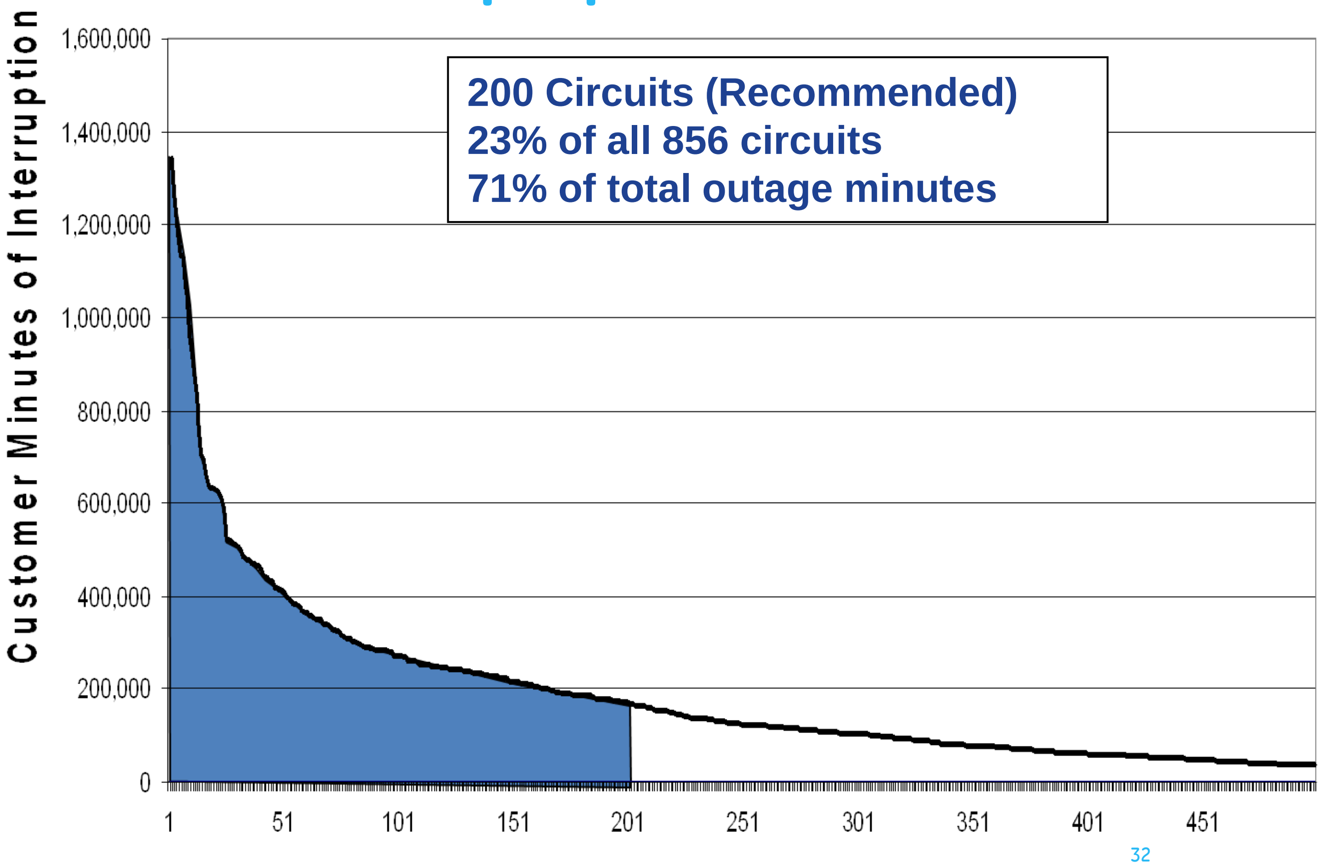
- Manually operate network (Switching Orders, interaction with crews)
- Static View of Network Configuration (Map-board, paper maps, etc.)

Base Level — *Manual control and legacy methods*

* Compared to base, from outage duration model

Are these Specific to Certain Circuits?

Yes – example prioritized based on SAIDI



Types of Data

Managing Data => “Operational” Data

Data that represents the **real-time status, performance, and loading** of power system equipment

This is the **fundamental information used by system operators** to monitor and control the power system

Examples:

- Circuit breaker open/closed status
- Line current (amperes)
- Bus voltages
- Transformer loading (real and reactive power)
- Substation alarms (high temperature, low

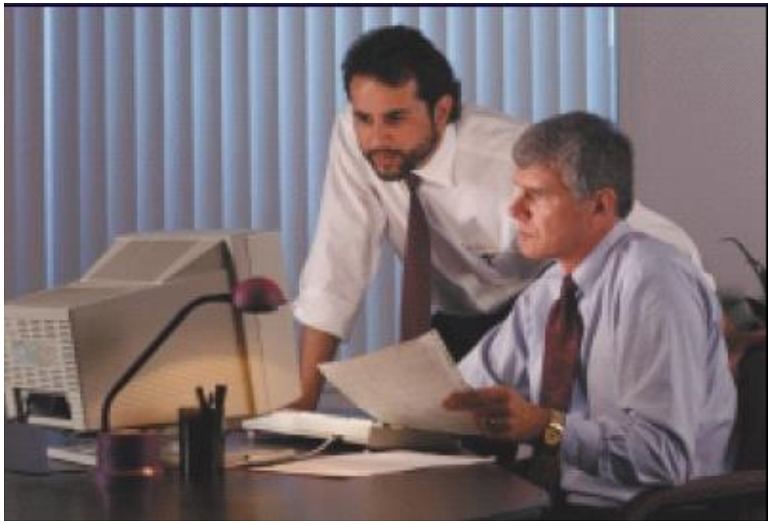
Managing Data => “Non-Operational” Data

Data items for which the **primary user is someone other than the system operators** (engineering, maintenance, etc.)

Note that operators are usually interested in some data that is classified as non-operational

Examples of “Non-Operational” data:

- Digital fault recorder records (waveforms) (protection engineer)
- Circuit breaker contact wear indicator (maintenance)
- Dissolved gas/moisture content in oil (maintenance)



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Characteristics of Operational and Non-Operational Data

Characteristic	*Operational Data*	*Non-Operational Data*
Data Format	Usually limited to **individual time sequenced data items**	**Usually a data file** that consists of a collection of related data elements
Real Time vs Historical	Usually consists of **real-time or near real-time** quantities	Mostly **historical** data: trends over time
Data Integration	Easily transportable by conventional SCADA RTUs using **standard (non-proprietary) protocols**	Typically use **vendor specific (proprietary) formats** that are not easily transported by SCADA communication protocols

Big Data, Analytics and Enterprise Data Management

Internet of Things (IoT)

Drive the next productivity revolution by connecting intelligent machines with people at work

The "II" Connects…

1. Intelligent Machines

Leverage technology & communication to cost-effectively connect machines

+2. Big Data & Analytics

Combine the power of big data, big analytics, and industry physics

+3. People at Work

Connecting people any place, any way, and any time for intelligent operations

= A world that works better, faster, safer, cleaner and cheaper

Energy Value:	**Global Energy Capex $1.9T/year**	→	**The first 1% annual savings equals $300B over 15 years**

Analytics

Meter Insight
(in development)

- Revenue Protection
- Power Quality and Reliability
- Load Forecasting and Research

Outage Insight
(in development)

- Automated KPI data validation
- Dynamic KPI dashboards
- Outage Event Recorder
- Planned outage optimization
- Predictive Outage Analytics
- Accurate ETR

Reliability Insight
(in development)

- Predictive vegetation management
- Asset health analysis
- System health analysis
- Lifecycle analysis and portfolio optimization

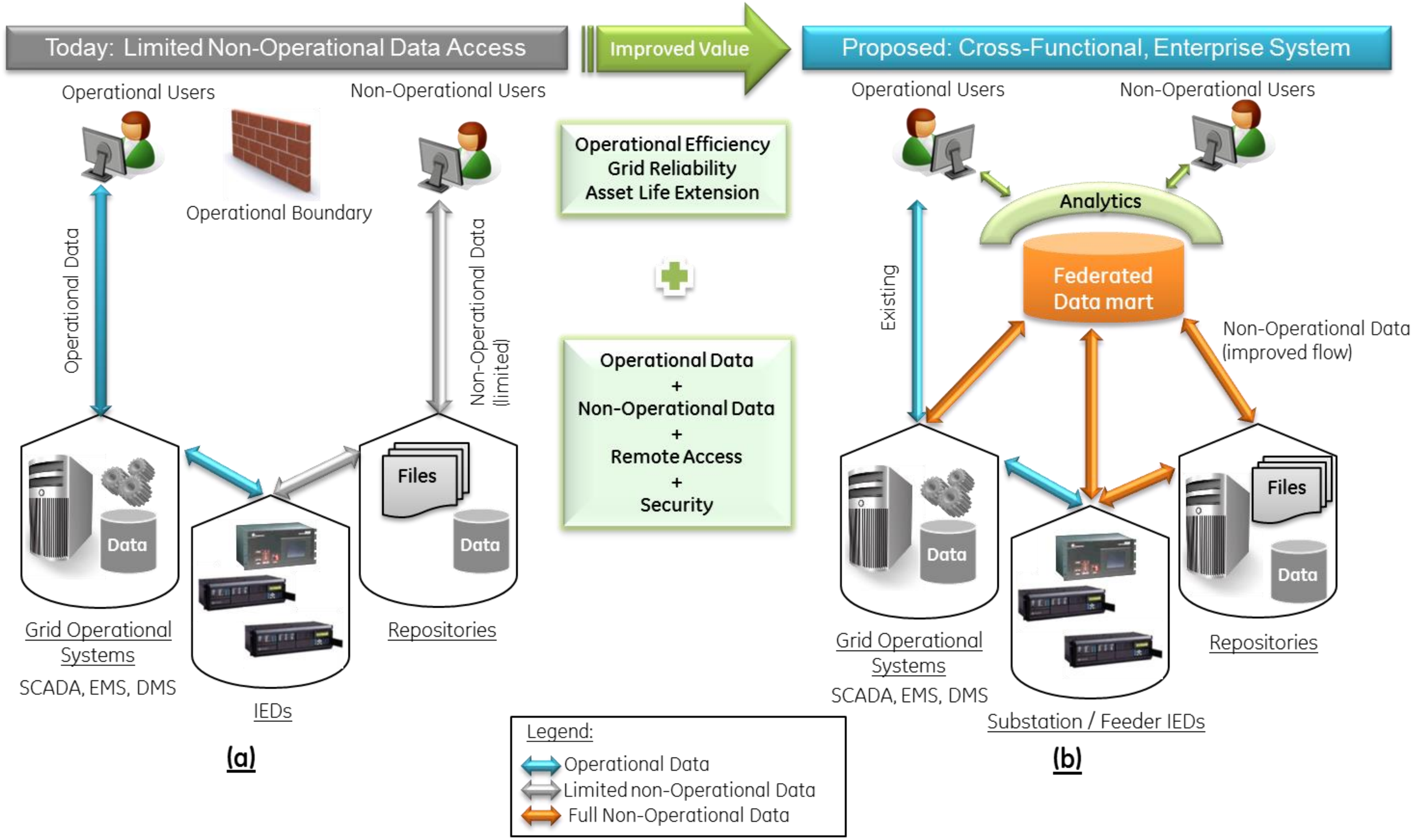
Renewables Insight
(in design)

- PV load (dis)aggregation/ hotspot analysis
- Wind load (dis)aggregation and hotspot analysis
- EV penetration/ impact analysis
- DER load orchestration

Consumer Insight
(in design)

- Social media integration
- Customer Segmentation
- Customer Engagement
- Sentiment Analysis

IT/OT Convergence and Data Access



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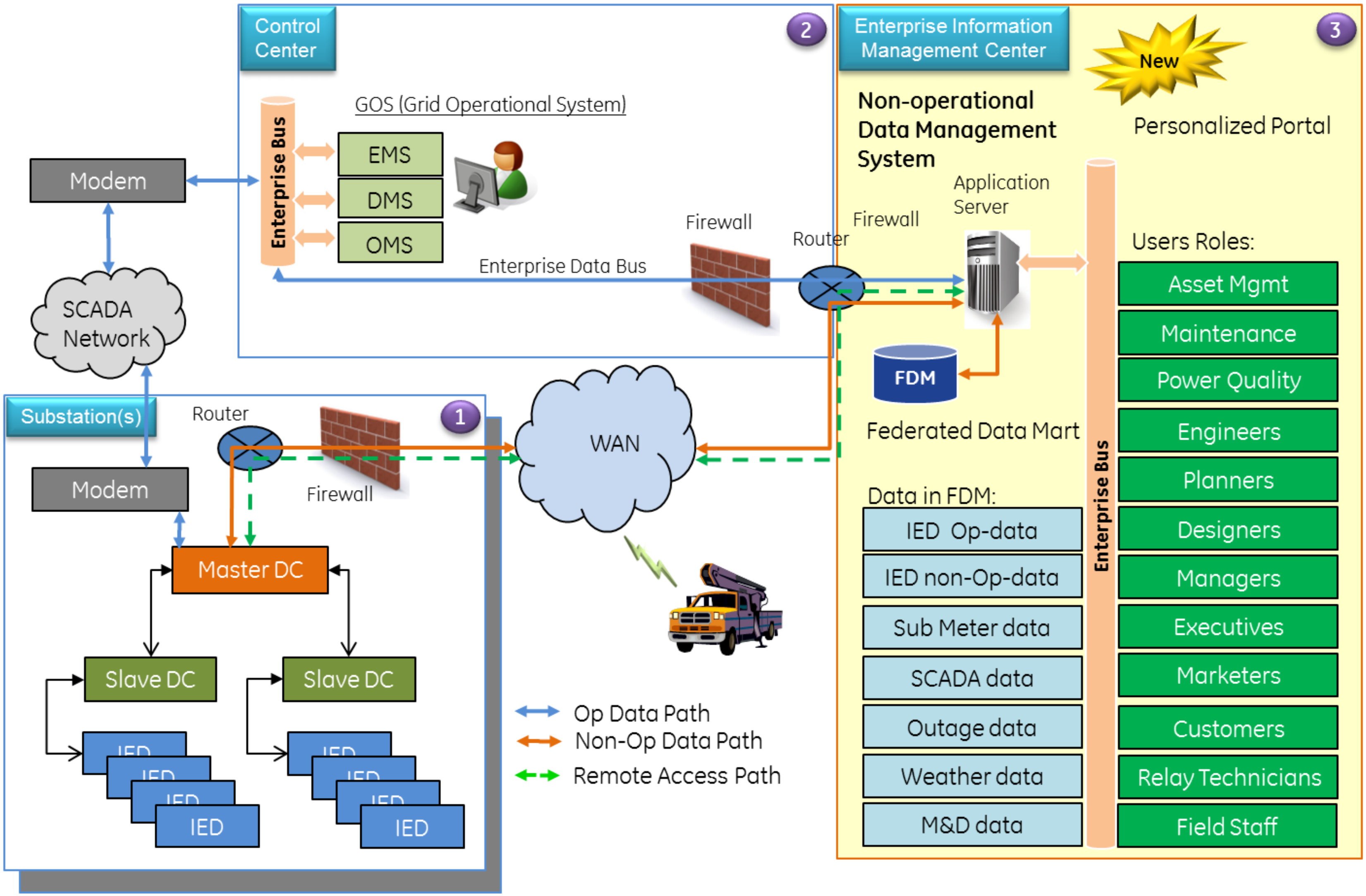
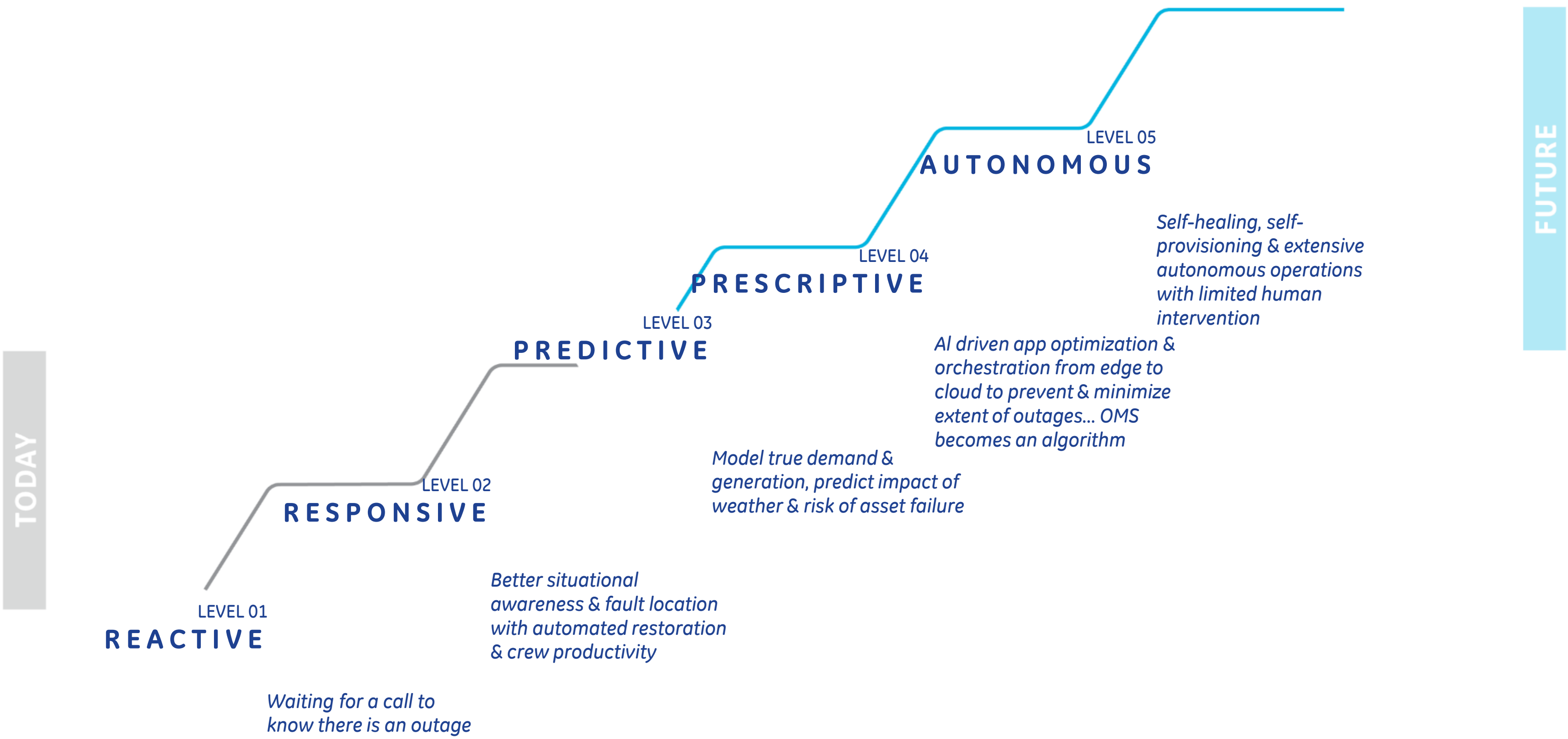
Realizing Greater Value From Data



The Journey to Digital Transformation



How to continue transforming network operations with predictive, prescriptive and, ultimately, autonomous solutions?

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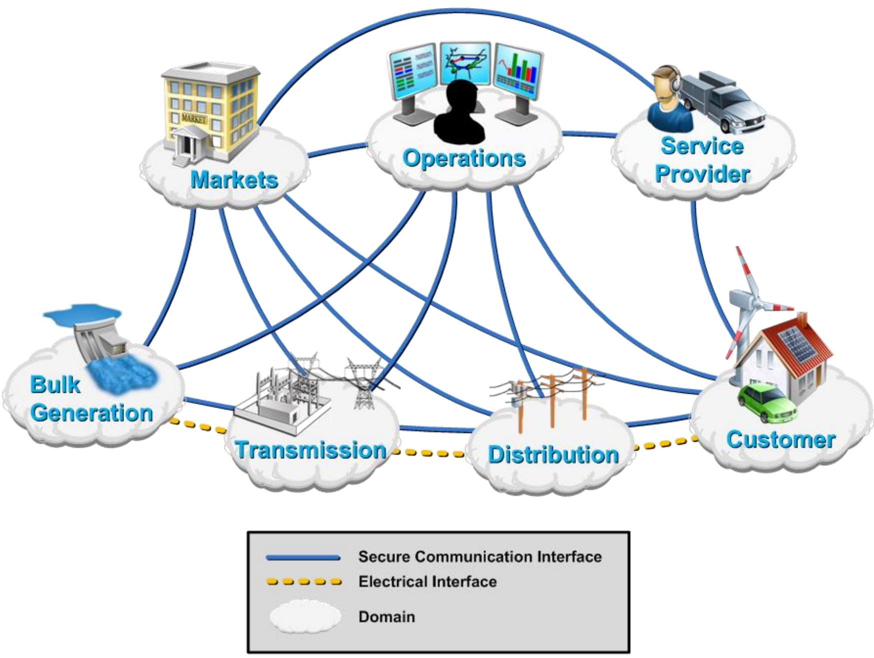
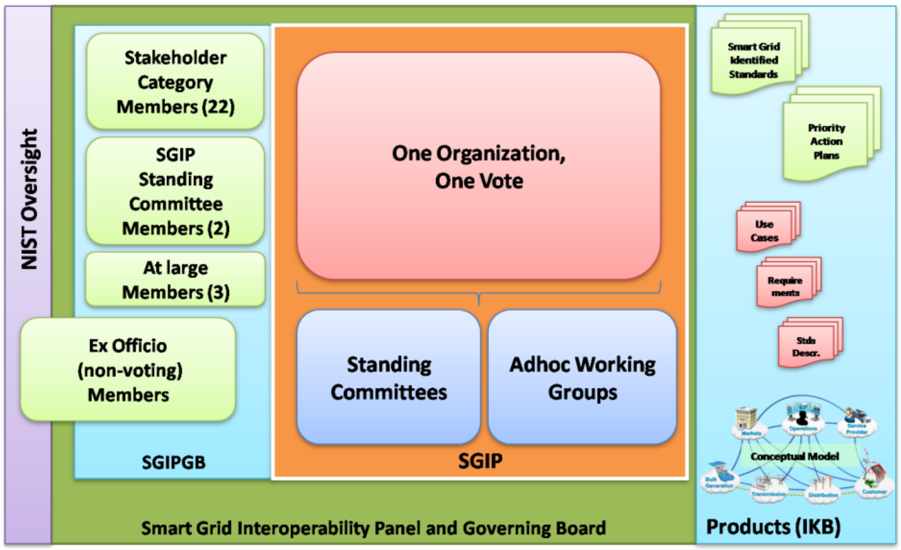
Smart Grid Standards and Interoperability

Example: Standards Framework

National Institute of Standards and Technology (NIST)

… Smart Grid Conceptual Reference Model
… Smart Grid Interoperability Panel Organizational Structure





NIST- Recognized Standards Release 1.0

Following the April 28-29 Smart Grid Interoperability workshop, NIST deemed that sufficient consensus has been achieved on 16 initial standards

On May 8, NIST announced intention to recognize these standards following 30 day comment period

NIST's announcement recognized that some of these standards will require further development and many additional standards will be needed.

NIST will recognize additional standards as consensus is achieved

Standard	Application
AMI-SEC System Security Requirements	Advanced metering infrastructure (AMI) and Smart Grid end-to-end security
ANSI C12.19/MC1219	Revenue metering information model
BACnet ANSI ASHRAE 135-2008/ISO 16484-5	Building automation
DNP3	Substation and feeder device automation
IEC 60870-6 / TASE.2	Inter-control center communications
IEC 61850	Substation automation and protection
IEC 61968/61970	Application level energy management system interfaces
IEC 62351 Parts 1-8	Information security for power system control operations
IEEE C37.118	Phasor measurement unit (PMU) communications
IEEE 1547	Physical and electrical interconnections between utility and distributed generation (DG)
IEEE 1686-2007	Security for intelligent electronic devices (IEDs)
NERC CIP 002-009	Cyber security standards for the bulk power system
NIST Special Publication (SP) 800-53, NIST SP 800-82	Cyber security standards and guidelines for federal information systems, including those for the bulk power system
Open Automated Demand Response (Open ADR)	Price responsive and direct load control
OpenHAN	Home Area Network device communication, measurement, and control
ZigBee/HomePlug Smart Energy Profile	Home Area Network (HAN) Device Communications and Information Model

Communication Protocols

Control Center to Control Center

- IEC 60870-6/TASE.2 – Inter-control Center Communications Protocol (ICCP)

Control Center to Field Equipment

- IEEE 1815 (DNP3) – North American Suppliers
- IEC 60870-5 – European Suppliers
  - 101 – serial communications
  - 103 – protection devices
  - 104 – TCP/IP (network communications)

Field Equipment

- IEC 61850 – substation automation and protection
- IEEE 1815 (DNP3) – substation and feeder device automation

Smart Grid Deployments

Lessons Learned

Smart Grid Lessons Learned

Technology:

- Challenge: “Hype” versus “Reality”
  - Utility expectations were that basic SG solutions were “shovel–ready”
  - Reality - Component technology was not as mature as advertised when combined to create a Smart Grid Solution
  - In many cases components were field re-engineered or upgraded to meet objectives and expectations
- Challenge: Integration / Interoperability
  - Integrating multiple supplier products to create a SG solution
  - Lesson Learned: adopt and insist on standards and open architecture methodology – drive for plug and play solutions
- Test, Test, Test
  - Lesson Learned: Extensive lab testing for “SG Solutions” is mandatory prior to implementation – understand the capabilities
  - Re-do’s are expensive and time consuming!

Smart Grid Lessons Learned

Implementation & Deployment:

- Challenge: Coordinating multiple suppliers
  - Managing equipment, shipments & delivery – pieces and parts along with assembly required for implementation (e.g., radio, controller, AMI network, substation equipment with software)
  - Coordinating software functionality with multi-supplier hardware and AMI
  - Lesson Learned: Minimize niche suppliers – prefer alliance suppliers with strong engineering and solution teams
- Challenge: Coordinating multiple internal departments
  - Managing Substation and Distribution Engineering, Protection and Control, Communications and Construction
  - Lesson Learned: Engage 1 Project Manager for each Smart Grid solution with multi-discipline authority
- Prefer packaged solutions from fewer suppliers – minimize the finger-pointing

Smart Grid Lessons Learned

Project Management:

- Establish Program Management Office
  - Multiple Project Managers reporting to the Program Manager
  - Adhere to PM guidelines such as Communication, Status Reporting, Risk Management, etc.
  - Build an "A" team with project and technical members – there will be challenges to collectively solve
- Establish Corporate Steering Committee
  - Key status meetings with Utility Executives and Alliance Suppliers
  - Escalation and Risk Mitigation in timely manner is critical
- Build Strategic Alliances with Key Suppliers
  - Define, Engineer and Build the Smart Grid solutions collectively
  - Alliance Supplier provides "On-site" management and technical support

Smart Grid Lessons Learned

Change Management:

- Smart Grid solutions involve multiple stakeholders (actors)
  - Residential / Commercial customers are now a "Major Stakeholder"
  - For example: PCT's, In-home devices, utility incentivized customer programs, 2-way communication with the Utility
- Define and develop "Use-Cases" for each component of Smart Grid
  - Use-Cases provide – a scenario description, defines the benefits, actors, functional requirements, and business rules and assumptions
  - Lesson Learned: Use-cases form the basis for the benefits achieved, functional requirements, development, and training
  - Smart Grid actors require "Significant Training" on the operation and maintenance of the deployed system (i.e., Operations Center, Communications, Customer Call Center, Engineering, Field Crews, etc.)

Thank You!